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Three Zone Scanning Protocol For Lung Ultrasound: An Anatomical Basis



Alistair G. Royse, MBBS, MD^{a,b,*}, Elaine Lui, MBBS, PhD^{c,d},
Dayu Gai, MBBS^d, Ximena Cid, MBBS, PhD^{a,e},
David Canty, MBBS, PhD^{a,f}, Andrew Wang, MBBS^a,
Lindsay Bridgford, MBBS^{a,g}, Colin F. Royse, MBBS, MD^{a,h,i}

^aDepartment of Surgery, The University of Melbourne, Melbourne, Vic, Australia

^bDepartment of Cardiothoracic Surgery, The Royal Melbourne Hospital, Melbourne, Vic, Australia

^cDepartment of Radiology, The University of Melbourne, Melbourne, Vic, Australia

^dDepartment of Radiology, The Royal Melbourne Hospital, Melbourne, Vic, Australia

^eDepartment of Medicine, The Royal Melbourne Hospital, Melbourne, Vic, Australia

^fDepartment of Anaesthesia, Monash Medical Centre, Melbourne, Vic, Australia

^gEmergency Department, Maroondah Hospital, Melbourne, Vic, Australia

^hDepartment of Anaesthesia, The Royal Melbourne Hospital, Melbourne, Vic, Australia

ⁱOutcomes Research Consortium, Cleveland Clinic, Cleveland, OH, USA

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Lung ultrasound is rapidly gaining popularity based on point of care ease of use, diagnostic fidelity and lack of ionising radiation. This was particularly notable at the beginning of the COVID-19 pandemic, where concerns of contamination of the x-ray department led to a reluctance to order frequent chest x-rays. Early COVID-19 lung involvement is of a bronchopneumonia, and patches of consolidation adjacent to the chest wall were easily detectable by ultrasound. A large number of proposed scanning protocols were advocated and are often complex and largely based on traditional stethoscope examination or access points on the chest wall rather than the underlying lung anatomy. A surgical understanding of lung anatomy and related surface anatomy has led us to develop a simplified three zone scanning protocol in 2013. The anterior zone corresponds to the upper lobe, and the posterior zone is divided between upper lobe and lower lobe. The relationship between lung lobes and the surface of the chest wall provides the anatomical basis for a simple three scanning zone lung ultrasound protocol.

Keywords

Lung ultrasound • POCUS • Simplified protocol

Introduction

Lung ultrasound is a rapidly emerging use for point of care ultrasound (POCUS). The advent of COVID-19 in 2020, led to a rapid uptake in the use of lung ultrasound and renewed interest in the examination protocols and reporting of findings. The ease of use of lung ultrasound at the bedside, with frequent repetition without ionising radiation allowed for a reduced reliance on conventional chest x-rays and the associated logistical problems of transport and of cleaning of the facility and equipment after exposure to a positive or suspected COVID patient. The most common finding was of patches of

lung consolidation adjacent to the chest wall, consistent with a bronchopneumonia. In contemporary non-COVID practice, assessment of basal lung collapse, pleural effusions, lung consolidation and pneumothorax are more convenient and more sensitive using lung ultrasound than for chest x-ray.

The use of lung ultrasound commenced with Lichtenstein in the mid-1970s. The basis for numerous scanning zones appears to have been heavily influenced by existing clinical practice with a stethoscope or a belief that precise location of lung pathology is important [1–12].

However, it does not necessarily follow that what appears logical when using a stethoscope, would automatically be

*Corresponding author at: Prof Alistair Royse MBBS, MD, FRACS, FCSANZ, GAICD, The University of Melbourne, The Royal Melbourne Hospital, PO Box 2135, Royal Melbourne Hospital, Parkville, Victoria 3050, Australia; Email: Alistair.Royse@gmail.com; Twitter: [@AlistairRoyse](https://twitter.com/AlistairRoyse)

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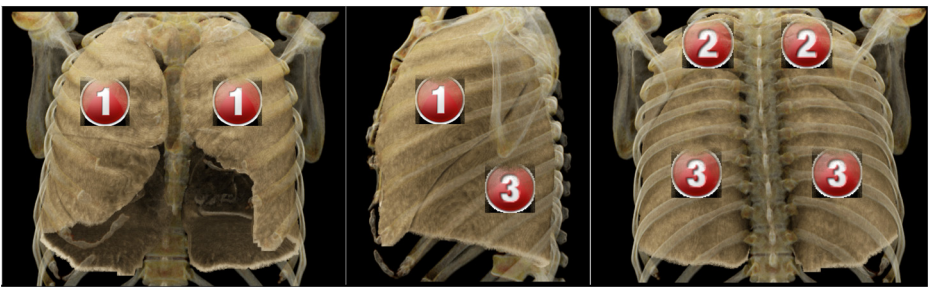


Figure 1 (Central Illustration)
1, Anterior, 2, Posterior Upper, 3, Posterior Lower. Scanning in zones 1 and 2 interrogates the upper lobe of lung, and scanning in zone 3 interrogates the lower lobe of lung.

appropriate for an entirely different technology such as ultrasound, since the ultrasound technology offers unique and independent diagnostic features. Specifically, use of ultrasound directly interrogates the anatomical location of the lung via the chest wall, and consequently an understanding of the relationship between chest wall surface anatomy and the underlying lung anatomy is important.

In 2013, we constructed a training course in lung ultrasound based on three anatomical zones to be scanned per side, based on the surface anatomy of the underlying lung,

according to the experience of the thoracic surgeon author (AGR) [13,14], (Figure 1, Central Illustration, Figure 2).

For POCUS users familiar with cardiac ultrasound where precise locality and angulation of the probe is critical, the concept of wide sweeps of the probe and large angulation changes for one single zone of interpretation may be at first difficult to accept. It may be the principal difference in lung versus cardiac ultrasound scanning.

The surface anatomy of the lung is demonstrated by a computed tomography (CT) scan with volume rendered

Patient Details										Study Details									
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Surname				First Name						Operator		Institution							
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Figure 2 iLungScan report.

three-dimensional (3D) reconstruction of a semitransparent chest wall, with bony structures overlying the lung. Development of a simplified protocol was part of an approved artificial intelligence project HREC66935, and Melbourne Health consent was waived. The anatomical findings were incorporated from the original scanning protocol of the iLungScan course. This new scanning protocol [13,14] was created at the University of Melbourne and has since been delivered as a training package for medical, nursing, physiotherapy and other allied health staff since 2013.

It is known that the surface anatomy of the lung may vary significantly in the presence of lung collapse, pleural effusion, chronic obstructive airways disease, phrenic nerve palsy, contralateral lung pathology or raised intra-abdominal pressure. Therefore, as a baseline evaluation (not reported here), three patients with normal lung anatomy were examined to ensure that there was consistency between their scanning results. One (1) patient was then subjected to 3D volume rendered image manipulation using syngo.via software, Cinematic rendering (Siemens, Healthineers, Forchheim, Germany).

Scanning Zones

Anterior Scanning Zone

The left and right upper lobes (LUL, RUL) occupy most of the anterior aspects of the chest, (Figure 3A). The lingula lobe of LUL lies inferiorly, adjacent to the heart; and the right middle lobe lies inferiorly adjacent to the heart. For the purposes of simplicity, both of these are considered in combination with the upper lobe (i.e. as “part of” the upper lobe for scanning purposes). These two lobes are small in volume, are rarely affected in isolation and cannot easily be separately distinguished from the upper lobes with ultrasound. The anterior extremity of both lower lobes does not generally reach the anterior chest wall.

Posterior Scanning Zones

The posterior aspect of the chest is divided into upper and lower parts (Figure 3B). In the normal lung, the apex of the lower lobe reaches the medial portion of the chest a little superior to the tip of the scapula. The fissure between the

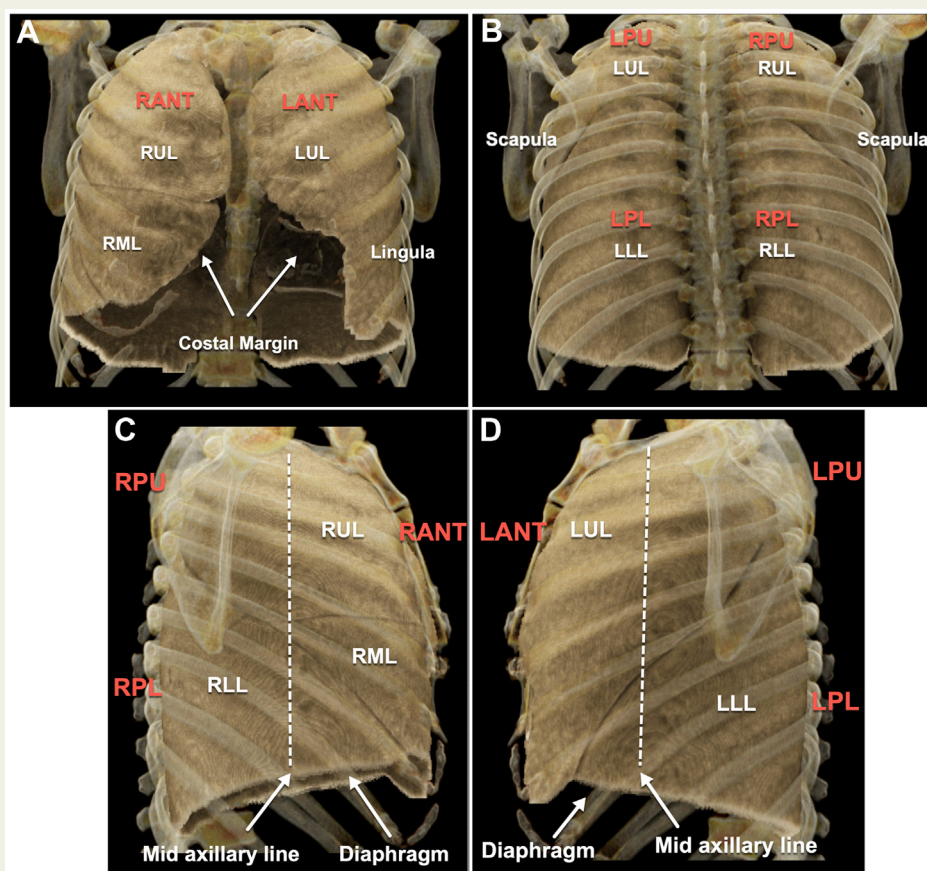


Figure 3 Anterior and posterior scanning zones.

A, anterior, B, posterior C right lateral, D left lateral: Lung lobes: RUL, LUL, RML, Lingula.

The apex of the lower lobes reaches to the midpoint of the scapula; whereas with lung collapse a variable position in relation to the scapula may occur, often closer to the inferior tip of the scapula.

Abbreviations: RANT, right anterior; LANT, left anterior; RUL, right upper lobe; LUL, left upper lobe; RML, right middle lobe; Lingula, lingula lobe of the left upper lobe.

upper and lower lobes runs adjacent to the medial border of the scapula.

Therefore, in the normal lung, approximately two-thirds of the posterior chest wall are occupied by the lower lobe and about one-third is occupied by the upper lobe. A significant proportion of the posterior chest wall is occupied by the scapula, preventing any ultrasound interrogation over the bony structure.

The original description in the Melbourne University iLungScan course differentiated between upper and lower posterior chest wall zones by a horizontal line drawn between the tip of both scapulae. This was a pragmatic division based on the easily identifiable bony landmark of the tip of the scapula on the basis that the bony landmark could be easily identified.

However, it is also important to understand that the presence of lung pathology, particularly of lung collapse with significant volume loss involving the lower lobe, significantly alters the lung position relative to the bony landmarks of the chest wall. Therefore, these CT scan illustrations are a guide only, and only pertinent to a normally inflated lung.

The Lateral Chest

The midaxillary line is anterior to the scapula and therefore has a relationship, predominantly, with the upper lobe (Figures 3C, 3D). At the lower extremity, a small portion of the lower lobe is imaged. Consequently, it is not considered additive to nominate the lateral chest wall as being a separate scanning zone, since the area being scanned is the same or similar to that being scanned from the anterior or posterior aspect. Specifically, most of the lateral chest wall imaging relates to the upper lobe, particularly for those patients who remain supine in bed (e.g. intubated patients in the intensive care unit), and where the direct posterior placement of the ultrasound probe is difficult or impossible.

Scanning of the Posterior Lung Zones From the Lateral Chest Wall

When direct posterior ultrasound scanning is not possible, a reasonable approximation of posterior lung imaging is possible from the lateral chest wall, by angling the ultrasound probe posteriorly, rather than maintaining trajectory at 90° to the chest wall. In the case of the upper lobe, the ultrasound signal then penetrates the chest wall, and deep to the scapula.

However, the posterior lung tissue is often not adequately imaged by this approach, as it relies on non-aerated lung, or pleural effusion, to allow transmission of the ultrasound signal from the site of the probe, all the way to the target lung tissue posteriorly. Consequently, an alternative technique commonly employed in the intensive care unit is to “log roll” the patient axially, to allow placement of the ultrasound probe against the posterior chest wall.

Comment

We have reported a 3D CT scan reconstruction to demonstrate that there is an anatomical basis to the simple three scanning zones per side approach.

Our argument against more numerous scanning zones is that the physical size of the lung lobes is substantially greater than small organs such as the heart, kidney or spleen. Therefore, examining two or three scanning areas on the anterior chest wall, from first principles, does not appear to enhance the clinical accuracy of fidelity. The lateral chest wall should not be categorised as a separate scanning zone as illustrated in Figures 1 and 3.

Lung pathology is usually confined within the boundaries of each anatomical lobe. Hence there is a rationale for considering pathology within lobes, representing different scanning zones.

The potential for bedside lung ultrasound to dramatically impact clinical practice is predicated on several factors. No ionising radiation is emitted improving long-term safety. The convenience of bed side assessment contemporaneously with overall clinical assessment by enhancing clinical diagnosis with imaged-based data would lead to improved diagnostic accuracy and would be expected to lead to earlier and to better clinical treatments. Further the ability to repeat assessments at the bed side improves management and reduces reliance on the resources of a radiology department and the logistics of transportation. The clarity of images of lung pathology in many settings, such as surgical, medical, emergency, intensive care and trauma practice, will support continued evolution of clinical assessment in the future by incorporation into the concept of ultrasound imaging augmenting conventional clinical and invasive pressure monitoring assessment.

Conclusion

We propose a simplified three zone scanning protocol for lung ultrasound that uses the surface anatomy of the chest to determine the underlying anatomy of the lobes of the lung.

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